Application of GIS in Ecological Land Type (ELT) mapping---A case in Changbai Mountain area

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Abstract: This paper depicted the physiographic landscape features and natural vegetation situation of study area (the eastern Jilin Province), and expatiates the definition, basic characters and its development of Ecological Land Classification (ELC). Based on the combination of relief map, satellite photography for study area and vegetation inventory data of 480 sample sites, a 5-class and a 15-class ecological land type map was concluded according to 4 important factors including slope, aspect, vegetation and elevation. Ecological Classification System (ECS) is a method to identify, characterize, and map ecosystems. The Ecological Land Type (ELT) was examined and applied initially in eastern Jilin Province.

Key words: Ecological Land Type (ELT); Ecological Classification System (ECS); Ecological land classification (ELC); Geographic Information system (GIS)
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Introduction

Since 1990's, the spatial information techniques such as Remote Sensing (RS), Geographic Information System (GIS), and Global Position System (GPS) have been improved increasingly in basic theories and techniques. They are making more and more effect on all kinds of ways. GIS has been used in a variety of contexts in ecology and forestry. Its function is increasing with the development of faster and more affordable computer technology. During the past 30 years, 3S has been used to carry out researches on Ecology Land Classification by North-American; they have obtained more achievement.

The aim of ECS is to provide a format to convey basic information on the biological and physical characteristics of the landscape in a concise, integrated, standard, and thorough manner for the purpose of ecosystem management. By mapping the combination of a landscape's various characteristics, ECS can help foresters to determine forest management methods based on the capabilities and suitability of landscapes. Each ecological land type had its own character, it's visualization through 3S technique and mapping has great practicability, which helps natural resource managers better understand the landscape's capabilities for supporting a forest, providing wildlife habitat, and producing a certain plant species. Owing to the changes in the forest policy and the increasing of ecological mapping activities in forests, future development of ECS should focus primarily on forest management and properly use of ecological data in the management and planning of forest resources.But in China, There are few researches on Ecology Land type by 3S techniques for lack of the relevant researches on Ecology classification system. Another reason is that 3S development is limited in China because of lagging management. So introducing advanced 3S techniques and pertinent classification system into forest modern management becomes imperative in current situation. Hence, there is an impending need to develop tools that can merge ecological theories into forestry practice. Ecological land type map developed by utilizing 3S techniques is the available step to this trouble. The concrete practice is to use spatial frameworks to stratify landscapes into relatively homogeneous regions (Shao *et al.* 2001), so the Jinsong Forestry Centre was selected to implement our pilot study on ELC in east mountain region of Jilin Province.

Background

Ecological Land Classification (ELC), a hierarchically structured, multifactor approach for mapping ecology units a multiple scales, has shown to be helpful in quantifying variation in fundamental ecological processes and response to management (Barnes *et al.* 1982, 1986; Host *et al.* 1986; 1988). It is a prerequisite for many ecologically-oriented management or planning applications, providing an essential framework for the identification of ecosystem elements and landscapes. The development of ecological land classifications is increasingly supported by digital satellite and terrain data that can be used to map land classes over large areas (e.g. Morissey and Strong

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1986; Franklin 1987), and by geographic information systems (GIS) for digital map overlay and spatial modeling. A potential advantage of GIS-based mapping of ecological land classes is that maps of terrain variables can readily be weighted and combined to display new or refined classification systems. Such flexibility is important because no single land classification is optimal for all ecological applications, especially when those applications span arrange of spatial and temporal scales and include widely divergent purposes.

Ecological Land Classification (ELC) is a cartographic approach to forestland delineation, and it defines units of land at different spatial scales that are hierarchical, nested, and homogeneous in their environmental and hierarchical vegetation characteristics. It is a process of delineating and classifying ecologically distinctive areas of the Earth's surface. Each area can be viewed as a discrete system, which has resulted from the mesh and interplay of the geologic, landform, soil, vegetative, climatic, wildlife, water, and human factors, which may be present. The dominance of any one or a number of these factors varies with the given ecological land unit. The holistic approach to land classification can be applied incrementally on a scale-related basis from site-specific ecosystems to very broad ecosystems. One of prerequisites of Ecological Land Classification (ELC) is to portray ecosystems at a level, scale, and intensity appropriate to the need.

Ecological land classification systems have recently been developed at continental regional state, and landscape scales. Hierarchical systems, using ecological principles in classifying land, have been developed for geographical scales ranging from global to local. Using a bioclimatic approach at a global scale, several researchers have developed ecological land classification (Bailey 1981). Other ecologically based classifications proposed at regional scales include those of Driscoll *et al.* (1984), in the United States and the Ecoregions Working Group (1989) in Canada. But no single system has the structure and flexibility necessary for developing ecological units at continental to local scales.

Ecological Classification System (ECS) uses multiple ecological factors and functional relationships among organisms and their environment to group similar forestland areas into groups called land types and differentiates other ecosystems into other groups. Ecological classification systems are defined by factors appropriate to a particular spatial scale. For example, maps at 1:250 000 are typically defined by mesoclimate and regional physiography, whereas 1:15 000 scale maps are defined in terms of soil texture and local ground flora. These fine-scale classifications have been used to develop forest management strategies, assess wildlife habitat, and plan other management operations (Georce *et al.* 1996).

Ecological Land Type (ELT) is one important part of forest ecosystem management. It is a forest service Ecological classification System (ECS) term for areas of land (with a minimum size of about acres), which have associations of several Ecological Land Type Phase (ELTP) units within them. By the ELT map that includes a landscape's various characteristics, ECS can help foresters to determine forest management methods based on the capability and adaptability of landscapes (Shao *et al.* 2001).

All of the Geo-information on ecosystem capturing, traversing, inputting, storing, disposing, outputting, employing is depending on the Geographical Information System technology involving Remote Sensing, Geographical Position System. Remote Sensing information disposes subsystem, which includes image pre-dispose system, auto-distill system and special subject maps developing system. It can capture update remote sensing information, then store in remote sensing database. Database management subsystem, which used to manage spatial database and attribute data, has the functions of the inputting, querying, updating, outputting and statistic analyses. This is the core in GIS. RS and GIS integration is the important part of system integration in MNRGIS. Remote sensing is the important data source and data updating means, and GIS is the assistant information in the data disposing of Remote sensing, which is used to support the semantic and unsemantic auto-distill (Zhang *et al.* 2001). While GIS is subsidiary information, both Attribute data and Graph data are the part of Database Management, and the Raster Data is affiliated to the Image Dispose (Fig .1).

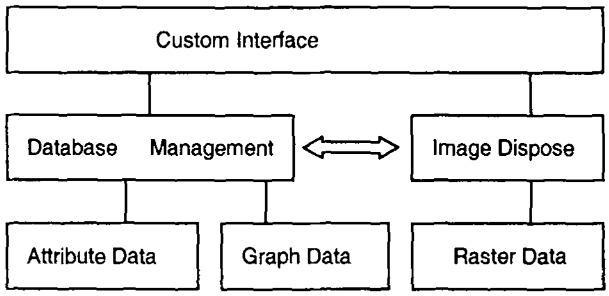

Fig. 1 Integration of remote sensing (RS) and geographical information system (GIS)

GIS will provide a tool for combining these separate themes of information, and representing the physical, biological, and social dimensions to define and map ecosystems.

Ecological unit map

The core of ECS is ecology unit. Ecological unit is a regionalization, classification and mapping system for stratifying the Earth into progressively smaller areas of increasingly uniform ecological potentials. Ecological types are classified and ecological units are mapped based on associations of those biotic and environmental factors that directly affect or indirectly express energy, moisture, and

nutrient gradients that regulate the structure and function of ecosystems. These factors include climate, physiography, water, soils, air, hydrology, and potential natural communities. Ecological unit delimits areas of different biological and physical potentials. Ecological unit maps can be coupled with inventories of existing vegetation, air quality, aquatic systems, wildlife, and human elements to characterize complexes of life and environment, or ecosystems. This information can be combined with our knowledge of various processes to facilitate a more ecological approach to resource planning, management, and research (Brooks *et al.* 1992). Ecological units provide basic information for natural resource planning and management; Ecological unit maps may be used for activities such as delineating ecosystems, assessing resources, conducting environmental analyses, establishing desired future conditions, and managing and monitoring natural resources (Kupfer *et al.* 2000).

The hierarchy of Ecological units provides a means of addressing spatial and temporal variations that affect the structure and function of ecosystems. This enables us to better evolve into ecosystem management. To implement ecosystem management, we need basic information about the nature and distribution of ecosystems. To develop his information, we need working definitions of ecosystems and supporting inventories of the components that comprise ecosystems. We also need to understand ecological patterns and processes, and the inter-relationships of the social and biological systems (Moss 1985). To meet these needs, we must obtain better information about the distribution and interaction of organisms and the environments in which they occur, including the demographics of species, the development and succession of communities, and the effects of human activities and land use on species and ecosystems. Research has a critical role in obtaining this information. Ecological units address the spatial distributions of relatively stable associations of ecological factors that affect ecosystems.

Although the basis for delineating individual ecological unit map is to capture the major ecological components and the relationships between each component, it is essential to capture their relative abundance and pattern. Abundance refers to the relative quantities of components associated with each map unit, and pattern concerns the arrangement of components vertically or horizontally. This process is directly opposed to traditional sector resource mapping as singular and independent items. Sector classifications are well suited for specific purposes and have been designed to meet focused needs. They have limitations, however, for state of environment and resource sustainability reporting which must consider linkages between issues and among the various components of the ecosystem. However, ecological classification, for a given level of generalization, gives up specific detail found in single sector surveys (e.g. forestry) in favor of more general data from several sectors (Davis *et al.* 1997).

Study area

Study area is located in Baihe Forestry Bureau (42°26′N, 128°26′E), which is in East Jilin Province, Northeast of China. Mean annual temperature is 5.0 °C, the lowest -17.06 °C in January, the highest 17.05 °C in July, precipitation 719.3 mm, and solar radiation 2015.3 h, and the period of frost-free 116 d. The soil type of the experiment is dark brawn. This research selects the Jinsong Forestry Centre of Baihe Forestry Bureau as the experimental unit.

Methods

The integration of the forest inventory and analysis of TM data is adopted as the main method. TM data used in this paper is from the satellite datum in 42°40′ N; 128°45′ E, and pixel is 25 m. The scale of topography map is 1:50 000. The map needs to be digitized to the digital elevation model (DEM), and then the multi-factor land type is available by the application of software Arcview and multifactor classification of land type.

On the current forest inventory within Jinsong forestry centre, we had mechanically chosen 480 inventory sites according to the kilometer gridding of map, and the distance between each site is 500 m. The quadrat of 20 m×30 m was set in each site. The understory vegetation, trees, shrub and grass, the characteristic of soil in each site were investigated and sampled. Site is a location, which is evaluated for components (including predicted potential natural vegetation if necessary) to determine the ELP of an area.

In this case, we discussed the multifactor classification that may comprise different ELT (local forest ecosystem types), each representing a distinctive combination of physiographic character, soil and vegetation. This result of classification is derived from the overlay analysis of multivariate analyses and data of sampling plots.

From an operational viewpoint, the objective is to produce a geographic reference framework that could be used to develop, on the basis of the same geographic contour lines, risks of disturbance or degradation of the environment (wind throw, erosion, landslide) and various other land capabilities to develop a truly integrator approach for the survey and analysis of natural resources (Belanger *et al.* 1992).

Results and discussion

The ecosystem classification has a hierarchical structure consisting of several levels owing to the differentia of natural physiographic character. Slope, aspect and elevation were selected as the main classification factors and discussed in this paper.

The slope can be represented in percent or degree, in Arcview, Derive Slope identifies the slope, or maximum rate of change, from each cell to its neighbors. The output slope

grid theme represents the degree of slope (e.g., 5 degree slope) for each cell location (Fig. 2). The landscape in northeastern mountainous areas of Jilin Province is generally hilly and can be differentiated into three terrain classes: flat sloping (0%-5%), moderate sloping (5%-20%) and the steep sloping (>20%). This distinction forms the highest level in the classification, separating hillslopes from ridgetops and ravine bottoms. The narrow ridge tops sampled were generally dry (xeric), while the site conditions of the ravine bottoms were wet-mesic (Hix *et al.* 1997).

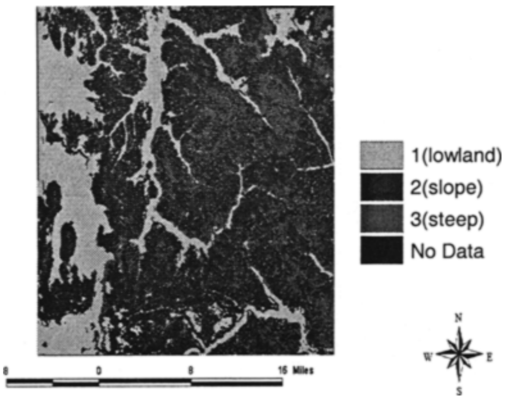

Fig. 2 Slope map of study area in the east of Jilin Province

The majority of the landscape is composed of moderate sloping terrain; the sub-classification in ELTS is derived from aspect. Relatively cool and moist northeast aspects (1-135°, 315-360°) are separated from the relative warm and dry southwest aspects (135-360°). The range soil moisture conditions on southwest slopes were dry to dry-mesic, while it was dry-mesic to mesic on northeast slopes. At the lowest level in the classification, the ELTS differed in slope position (Fig.3).

According to the feature of the Northeast of Jilin Province, the 5-class ELTS (Table 1) were achieved by the consideration of the slope and the aspect at the same time. So the landscape in study area is divided into 5 elts in term of slope and aspect (Fig.4).

Based on the GIS software Arcview 3.2, the 5 classes of ELT is concluded seeing the following program:

Avenue Command: Con

Syntax: aGrid. Con (yesG NewFile = (Slope = 1). Con (1, (Aspect = 1). Con (2, 3)

(([Slope2]= 1). Con (1, [Slope2] = 2). Con (([Aspect2] = 1). Con (2,3), ([Aspect2] = 1).Con(4,5))))

Where,

The slope file: 1 = low land or ridge
2 = slope
3 = steep

The aspect file: 1 = north-facing slope
2 = south-facing slope

Form a new file: 1 = low land or ridge
2 = mesic slope
3 = dry slope
4 = mesic sleep
5 = dry sleep

Table 1. Classification of ELT on the northeast mountainous area of Jilin Province based on the slope and aspects

ELT	Slope	Aspect	Description
elt1	<5%		Wet-mesic ravine bottoms (valley)
elt2	5-20%	135-315°	Moderate sloping terrain, Facing south
elt3	5-20%	<135° or >315°	Moderate sloping terrain, Facing north
elt4	>20%	135-315°	Steep sloping terrain, facing south
elt5	>20%	<135° or >315°	Steep sloping terrain, facing north
elt0			Flat sloping terrain; Dry narrow ridge tops (ridge)

Note: Because the area of ridge accounts for very small quantity, the elt0 is ignored in the final result.

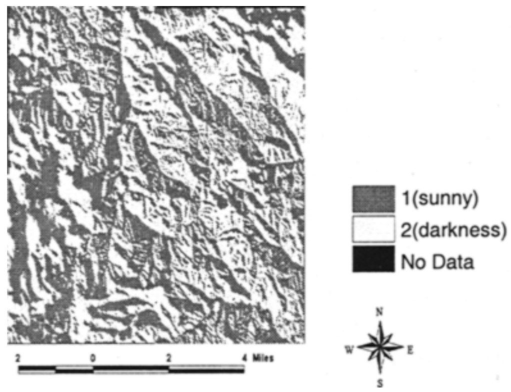

Fig. 3 Aspect map of study area in the east of Jilin Province

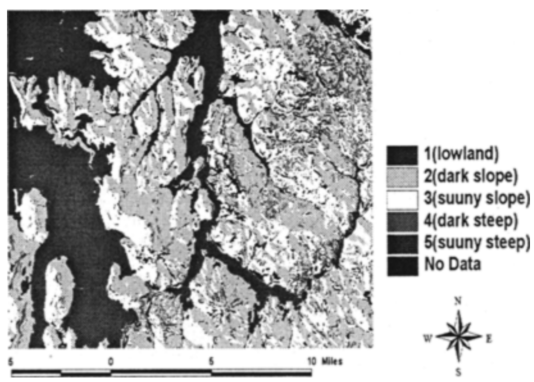

Fig. 4 ELT (5-class) map under the topology of study area

Because different elevations have different kinds of vegetation, elevations can reflect vegetations. In this case, the third factor, elevation, was added into the final classification in the study area. The landscape in northeast of Jilin Province is generally differentiated into three classes, Low elevation is under 700 m, moderate elevation ranges 700 m to 1 100m, and high elevation is over 1 100 m. The most landscape is composed of low and moderate elevation. Based on the previous 5-class ELTs, the 15-class ELTs were concluded out by merging the elevation with the topology in Arcview 3.2. They were lowland and low elevation (elt1), lowland and moderate elevation (elt2), lowland and high elevation (elt3), slope sunny and low elevation (elt4), slope sunny and Moderate elevation (elt5), slope sunny and high elevation (elt6), steep sunny and Moderate elevation (elt7), steep sunny and Moderate elevation (elt8), steep sunny and high elevation (elt9), steep dark and low elevation (elt10), steep dark and moderate elevation (elt11), steep dark and high elevation (elt12), slope dark and Low elevation (elt13), slope dark and moderate elevation (elt14), slope dark and high elevation (elt15), (Fig.5).

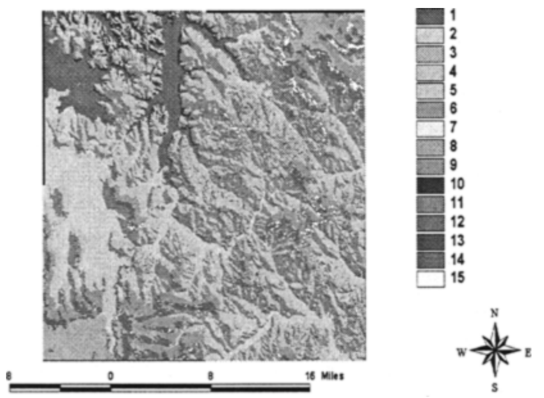

Fig. 5 ELT (15-class) map based on elevation of study area

Conclusions

Based on the classification factors including slope, aspect and elevation, a 5–class system of ELT and a 15-class system of ELT of study area were presented, 5–class system of ELT was based on the two factors slope and aspect of study area (Jinsong Forestry Centre), 15-class system of ELT was brought forward by the add of elevation character.

It was suited to the mountain region in eastern Jilin Province that the slop was divided into flat (under 5%), Slope (5-20%), steep (over 20%) and the aspect facing south (135-315°), facing north (0-135° or 315-360°), the elevation low (under 700 m), moderate (700-1 100 m), high (over 1 100 m).

This ecology land type and corresponding result can be extended to other regions, which have the parallel characteristics in physiographic characteristic and vegetation situation, particularly in eastern regions in China.

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